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Echoic and Self-Echoic Responses in Children

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Eleven typically developing children were assessed on the accuracy of prompted self-echoic responses following a 5-s delay from their initial echoic response, replicating procedures in Esch, Esch, McCart, and Petursdottir (2010) that compared discrepancies between echoic and self-echoic scores of autistic and typically developing children following a 2-s delay. We compared the two studies in terms of age, level tested, and echoic/self-echoic discrepancy scores. Age and test level differences were found to be statistically significant. Results are discussed in terms of discrepant self-echoic performance and self-echoic rehearsal as it relates to participant age, test level, motivating variables, and the development of complex behavior.

Key words: echoic, self-echoic, self-echoic rehearsal, mnemonic behavior, motivation

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An echoic response is defined as verbal behavior that shares point-to-point correspondence with the vocal-verbal stimulus that evokes it (Skinner, 1957). Acquisition of other verbal operants may be facilitated by a strong echoic repertoire, including the self-echoic (Skinner, p. 64) in which a speaker who hears his or her own ‘‘response’’ (as auditory stimuli) echoes those self-produced stimuli. Such self-echoic responding can be reinforced automatically if its emission controls further aspects of the speaker's verbal behavior (Vaughan & Michael, 1982). As a rehearsal, a self-echoic (SE) response functions as a member of a mnemonic response class for solving a problem (Donahoe & Palmer, 1994); additionally, it is thought to be involved in complex behaviors such as naming (Horne & Lowe, 1996) and those emitted under joint control (Lowenkron, 1998). However, assessing an echoic repertoire may be insufficient for assessing the strength of an SE repertoire where a listener and speaker are in the same skin.

An earlier investigation (Esch, Esch, McCart, & Petursdottir, 2010) developed a procedure to determine if discrepancies exist between echoic and self-echoic responses in typically developing (TD) children and those diagnosed with autism spectrum disorders (ASD). Following initial assessments to determine how many numerals a participant could echo and to identify stimuli that evoked SE responses, we said a series of numbers to participants and instructed them to echo what they heard; after 2 s, we prompted them to self-echo (e.g., ‘‘What?’’). Results indicated that children with ASD diagnoses were more likely than TD peers to show discrepancies between echoic and SE responses, suggesting that those with ASD may have more difficulty repeating their own vocal behavior (SE) than the vocal behavior of others (ECH).

Fewer and less discrepant differences between echoic and SE responses by TD children relative to their ASD peers in our earlier study prompted the current descriptive pilot study. The goal was to provide preliminary data on the difference between TD children's accuracy in echoic and self-echoic trials with a 5-s delay to the self-echoic prompt (versus the earlier study's 2-s delay). Previously, it was unclear if responding during SE was primarily controlled by the child's own echoic response product or, to some degree, by the auditory stimulus presented by the experimenter during the procedure's echoic component. Indeed, the SE results for three children, for whom an incorrect echoic response was ‘‘self-corrected’’ (i.e., matched the ECH model) during the SE component of the trial, suggest that some responses during SE may have been controlled by the experimenter's vocal model. Thus, to make the

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participants' echoic responses more salient to control SE responses, the current study increased the delay from 2 s to 5 s between the echoic response and the request for the subsequent self-echoic response.

METHOD

Participants and Setting

Eleven typically developing children, seven males and four females, from 3 to 8 years of age, participated in the present study (see Table 1, upper panel). Participants attended a single 15- to 20-min session located in an office area of a daycare center. Session items were a video camera, a small table and chairs, data sheets, token cards, tokens, and a container of toys and stickers.

Response Definitions

The dependent variables were participants' ECH and SE responses. ECH responses were scored as correct, incorrect, or no response. A correct ECH met the following criteria: (a) it had point-to-point correspondence with the antecedent auditory stimulus, and (b) it occurred within 2 s of the model. If a response was misarticulated, but closely approximated the echoic model (e.g., *fwee* for *three*), it was counted as correct. An incorrect ECH either (a) did not match the ECH model, or (b) did not occur within 2 s of that model. The self-echoic prompt was a verbal prompt by the experimenter to evoke a vocal-verbal response; to the extent this response was controlled by the participant's previous ECH response, it would match that previous response; thus, it was termed a self-echoic response. The first vocal response that occurred within 2 s of the self-echoic prompt was scored as the SE. SE responses were scored as correct, incorrect, no response, or edited (EDIT). An SE was scored correct when it matched the participant's own correct or incorrect ECH and occurred within 2 s of the experimenter's self-echoic prompt. An SE was incorrect if any part did not match the participant's own ECH response or did not occur within 2 s of the self-echoic prompt. The experimenter recorded no response if the participant did not respond within 2 s of the self-echoic prompt. An SE was scored EDIT when the participant correctly echoed the experimenter's initial model following the participants' own incorrect ECH.

Participant speech behaviors during the 5-s delay (i.e., those that might have functioned as ''rehearsals'') were broadly categorized according to their observability (see Table 2). *Vocalization* responses were defined as those in which a participant overtly repeated numbers. *Lip movement only* responses were identified as those where overt lip movements appeared to form numbers, although no vocalization was detectible. Responses were coded *No lip movement or vocalization* when no rehearsal was observed; *Not observable* was coded when no vocalization occurred and the participant's mouth was not visible on camera.

Interobserver Agreement

Two independent observers recorded, *in vivo* or from videotapes, 100% of participant responses from all sessions. Interobserver agreement (IOA) was calculated on a trial-by-trial basis on echoic and self-echoic components of the experiment. Average agreement for participants was 100% for ECH responses and 99.1% for SE responses (range, 90% to 100%).

Procedural Integrity

Procedural integrity was calculated for each participant by dividing the number of correctly presented trials (i.e., ECH/SE and distracter) by the sum of correct and incorrect trials and multiplying by 100%. The procedural integrity percentage for all participants was 95.8% (range, 50% to 100%). The lower range calculation (50%) reflects one session during which the experimenter delivered the self-echoic prompt following a delay that was 1–2 s greater than the 5 s (plus or minus one) criteria on 5 of the 10 trials.

Procedure

The purpose of this study was to determine differences in participant's ECH and SE responses with a 5-s delay between the participant's ECH response and the self-echoic prompt. Immediately prior to the

Table 1
Participant Characteristics and Test Result Summaries From Current Study and From Esch et al. (2010)

Participant number	Gender (F/M)	Age at testing (years-months)	Test level[a]	Leads used[b]	Score (Total = 10)	
					Echoic	Self-echoic
Current Study						
8	M	3-0	3	4	9	9
1	F	4-0	5	4	4	7
10	M	4-6	4	4	10	7
7	M	4-10	5	4	10	5
2	M	5-6	4	4	8	4
3	F	6-0	5	4	10	5
4	M	6-0	4	4	10	6
5	M	6-0	4	4	9	6
6	F	6-11	5	4	8	2
9	M	7-7	4	4	10	9
11	M	8-0	4	4	10	10
Esch et al. (2010)						
106	F	2-1	1	4	9	6
107	F	2-2	2	4	10	7
113	M	3-0	3	4	9	9
109	M	3-1	3	4	9	10
108	M	3-3	4	4	8	2
101	F	3-4	3	4	10	8
105	M	3-6	2	4	10	9
111	M	4-0	3	4	10	10
104	F	4-4	4	4	7	9
102	F	4-6	3	4	10	9
110	F	4-9	4	4	10	10
112	M	4-11	4	4	10	10
103	M	5-5	4	4	7	8
114	M	7-11	6	4	9	7

[a] Number of digits presented during echoic trials.
[b] Number of different experimenter prompts (e.g., *What? Huh?*) that evoked a child's self-echoic response.

experiment, two pretests were conducted to determine (a) the digit span each participant would echo and (b) the prompts that would evoke a self-echoic response. The experiment consisted of 10 trials each containing an ECH component followed by an SE component; these 10 ECH/SE trials were randomly interspersed with 10 distracter trials.

Pre-experimental assessments. During the *echoic pretest*, the experimenter asked participants to repeat one or more numerals (e.g., *Say* ''three''). Numerals were selected from a random number list and contained only one syllable (''seven'' was omitted). Level 1 consisted of only one numeral; Level 2 had 2 digits, and so on, up to Level 9, which contained 9 numerals. Each level offered 3 sets of numerals. For example, Level 2 consisted of Set A (9–5), Set B (10–4), and Set C (1–6). Sets were presented until a participant made two set errors at a particular level. The level immediately below that ceiling level was used in the echoic component of the experiment.

During the *self-echoic prompt pretest*, the experimenter showed participants pictures of up to five common objects (e.g., cat). Upon the participant's correctly naming the picture, the experimenter removed the picture and, following a 5-s delay, asked the participant to repeat. One of four prompts was used (''What?'' ''Huh?'' ''What did you say? '' ''Say it again.''). Prompts that evoked vocal-verbal responses were used in the self-echoic component of the experiment.

ECH/SE trials. The experimenter spoke numerals at a rate of approximately 3 per s and asked participants to repeat them. If the participant was not looking, the experimenter said ''Ready?'' and waited for eye contact prior to saying the numbers. Following each ECH response, the experimenter looked away for 5 s (silently counting 1-one thousand, 2-one thousand, etc.) and then presented the self-echoic prompt (e.g., ''What?''), initiating the self-echoic component of the trial. There were no programmed consequences following ECH or SE responses.

Distracter trials. Distracter trials were alternated with ECH/SE trials. The experimenter presented a 3-picture array listener task (e.g., *point to shoe*) or a 2-picture visual matching task (e.g., *match cat*); neither task required participants to vocalize. Although prompts for responding were programmed, all children completed the distracter tasks independently. Each task response was followed by praise and a token, which the child then affixed to a token board with a clothespin. The experimenter then placed the board aside until after the next distracter task was completed at which time the praise-token delivery process was repeated. After each session, children were given an opportunity to exchange tokens by selecting a sticker from an available array.

RESULTS AND DISCUSSION

Typically developing children were asked to self-echo, after a 5-s delay, their previous echoic (ECH) response to the experimenter's auditory model of a series of numerals. The upper panel of Table 1 shows participants' ages and gender, number of digits presented (i.e., Level), number of self-echoic (SE) prompt topographies used, and the number of correct ECH and SE responses during the procedure. For reference, the lower panel depicts the same information from Esch et al. (2010). Pre-experimental assessments showed that participants correctly echoed three to five digits and responded to all four SE prompt topographies. Figure 1 compares current ECH/SE results with data from the previous study. The graph's diagonal line represents points at which there would be an equal number of correct ECH and SE responses. Data points below the line represent scores that contained fewer correct SE than correct ECH responses. All but one of the current participants (closed circles) scored at or above 80% on echoic trials, which suggests that the pre-experimental ECH assessment procedure is adequate to identify appropriate stimuli (i.e., Levels) for similar ECH/SE investigations. Of these participants, eight children emitted 9 or 10 correct echoic responses, but only three scored similarly (9 or 10 correct) on the SE component. The percentage of correct SE responses ranged from 20% (n = 1) to 100% (n = 1). A difference score was calculated for each participant by subtracting the SE score from the ECH score.

We examined ECH/SE performance differences for current participants responding to a 5-s delay and for those TD participants in the earlier investigation in which a 2-s delay was imposed before the SE prompt. Our data indicate no significant difference between performances of current participants (M = 2.55, SD = 2.73) and previous participants (M = 1.00, SD = 2.08), $t(23) = 1.56$, p = 0.137. Despite the lack of statistical significance, several differences are noteworthy and may have implications for future SE research. In the earlier study, ECH/SE discrepancy scores varied minimally (i.e., by one response) for 8 of 14 (57%) TD children, indicating that most children self-echoed reliably what they had just (after 2 s) heard themselves say. By contrast, after a 5-s delay in the current study, only 27% (3 of 11) children had ECH/SE scores that were similarly discrepant. One possible explanation for these results is that a 5-s (vs 2-s) delay weakens stimulus control for an SE response to what was recently heard. During longer temporal delays, competing environmental stimuli have more opportunity to disrupt mnemonic responding (e.g., rehearsal) related to the ECH stimulus, a problem assuming that rehearsal keeps a distal or weakening stimulus salient until reinforcement is available. Further, weak motivation

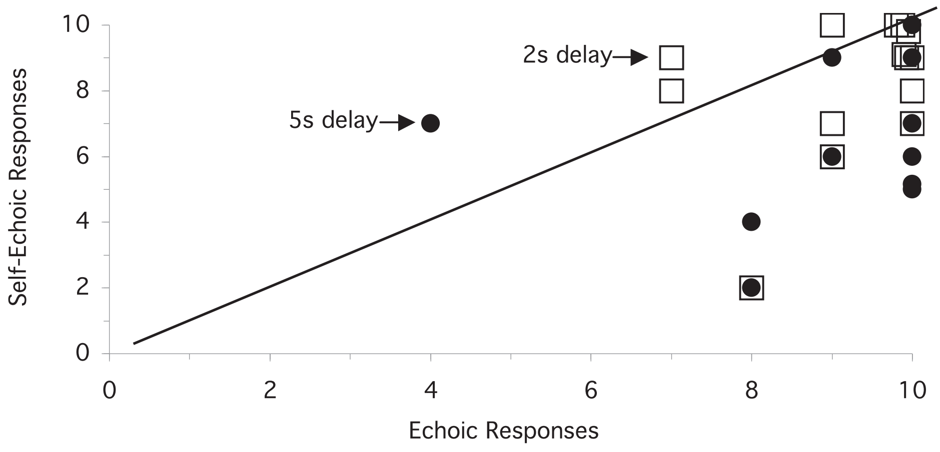

Figure 1. Correct echoic and self-echoic scores in typically developing children. Open squares represent ECH/SE scores with a 2-s delay (Esch et al., 2010). Closed circles display current ECH/SE scores with a 5-s delay.

for an available consequence may reduce the probability of engaging in such repetition. Lacking pen and paper, one may be less likely to rehearse the address of a musty garage sale than that of a trendy new coffee shop where a friend awaits. Longer delays and/or weak or absent motivation to engage in rehearsal may make it more likely that children will respond to (indeed, perhaps even produce) other stimuli overtly or covertly, such as singing to themselves or tacting things in the environment. Participant 8 provides an example of this when, during the 5-s delay after correctly echoing the ECH model, he said ''I hear a train'' followed by an incorrect SE response.

It is possible that ECH skills are related to developmental differences. We found statistically significant differences between both participant ages and test levels used in the two studies. Children in the current study were older (M = 5 years, 8 months, range 3 to 8 years) than their 2010 counterparts (M = 4 years, 0 months, range 2 to 7 years), $t(23) = 2.72$, $p = 0.012$. In addition, they tested (i.e., passed the ECH pre-test) at a higher level ($M = 4.27$; range, Level 3 to 5) than TD children in the earlier study ($M = 3.29$; range, Level 1 to 6), $t(23) = 2.45$, $p = 0.022$. In other words, older participants echoed longer numeric strings than did younger participants. However, it is not clear whether self-echoic repertoires develop in tandem with ECH nor whether these are necessarily acquired developmentally. For example, a 6-year-old participant showed low correspondence between ECH and SE despite rehearsing (i.e., self-echoing) during the delay period; conversely, the youngest participant (3 years) scored 9 out of 10 on both ECH and SE and emitted no rehearsal behavior during the delay. Table 2 shows participant behavior during this period that ranged from (a) overt (audible) repetition of numbers to (b) overt lip movements that appeared to form number words to (c) no detectible rehearsal. Of 92 observable trials, rehearsal occurred on 16 trials (17%) by 4 of 10 participants (Participant 2's data were not available for this analysis), one who vocalized and 3 who emitted only lip movements. Of all participants with the highest ECH/SE correspondence, or least discrepant scores (see Table 1), Participant 8 (age 3) and Participant 11 (age 8) did not overtly rehearse, whereas Participant 9 (age 7) only began to overtly rehearse subsequent to an SE error and continued for 5 of the remaining 7 trials. These data suggest that some children have access to mediational behavior (such as covert self-echoic rehearsal) that is sufficiently strong to produce a correct delayed SE; thus overt rehearsal is no longer needed. However, when verbal contingencies require a stronger mediating response, as it did following Participant 9's SE error, overt rehearsal comes to strength. Overt responding may have served

Table 2
Number of Trials with Rehearsal During 5-s delay

Participant number	Vocalization	Lip movement only	No lip movement or vocalization	Not observable
1	0	7	2	1
3	3	0	4	3
4	0	0	7	3
5	0	0	9	1
6	0	0	10	0
7	0	0	10	0
8	0	0	10	0
9	0	5	5	0
10	0	1	9	0
11	0	0	10	0

a mediating, or rehearsal function, although signs of overt rehearsal did not strongly predict greater homogeneity between ECH and SE scores; in fact, these variables were negatively correlated ($r = -0.560$, $p = 0.092$). Among participants with the least ECH/SE correspondence (i.e., most discrepant scores), Participants 6 and 7 (almost 7 and 5 years old, respectively) engaged in no overt rehearsal during the delay (both reported several times that they ''didn't remember'' or ''forgot''). Participant 3 (age 6) rehearsed on only 3 (of 10) trials. Participant 1 (age 4) started rehearsing only following an SE error and was the only child whose SE score exceeded the ECH score due to correctly self-echoing (six) incorrect echoic responses. Thus, her performance alone may have affected the correlation reported above.

Taken together, these data suggest that SE behavior is not reliably recruited during delayed opportunity to respond, particularly (as in this study) when no programmed reinforcement is available. Furthermore, it may be necessary to specifically instruct it. This is especially important to the extent that an SE repertoire facilitates more complex problem solving such as mnemonic responding (Donahoe & Palmer, 1994) or engaging in *listening behavior* (Schlinger, 2008).

Larger discrepancy scores (although not statistically significant) in the present study relative to Esch et al. (2010) may be an artifact of the delay itself. There was no delay between ECH model and response, in contrast to the 5-s delay between the auditory stimulus produced by the ECH response and the SE prompt. The discrepancy between ECH responding and SE responding might be less were there equal delays to both responses. The introduction of a longer delay may result in the deterioration of any echoic response, whether it is self-echoic or not. This means that the difference between echoic and self-echoic responses in the present study could in fact be the difference between an immediate echoic response (the ECH response) and a delayed echoic response (the SE response). Additional controls would be needed to separate these issues. For instance, future researchers could observe effects of varying delays for *any* opportunity to respond (e.g., comparing delays from ECH model to ECH response and to SE response).

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